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THE LONG-TERM LIGHT CURVE OF THE CATACLYSMIC VARIABLE V794 AQUILAE

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ABSTRACT

The 1990–2012 light curve of the nova-like (NL) cataclysmic variable V794 Aql is studied in order to characterize and better understand the transitions to and from the faint state, and the variations within the bright state. Investigations of earlier portions of this data had concluded that the transitions to the low state were much slower than the rapid recovery, giving a sawtoothed appearance to the light curve. This behavior differs from that of most other VY Scl stars, which led to an interpretation of the large amplitude sawtooths as being due to an accretion disk (AD) instability. However, more recent photometry strongly suggests that the bright state itself has transitions of 1–1.5 mag, and that earlier studies had intermixed these bright state variations with the transitions to the low state. These newly recognized variations within the bright state sometimes appear as small outbursts (OBs) with typical amplitudes of 0.5–1.5 mag and spacings of ∼15–50 days. The rise times of the OBs are 2–3 times faster than the decline times. We argue that the V794 Aql bright state variations are due to AD behavior similar to that seen in dwarf novae, but with varying degrees of stability. Similar regular small OBs have also been reported in other NL CVs, which we compare with V794 Aql. The true deep low states in V794 Aql appear to be normal, having transition speeds and shapes very similar to the transitions in other VY Scl stars.

Key words: cataclysmic variables – stars: individual (V794 Aql)

Online-only material: machine-readable and VO tables

1. INTRODUCTION

Cataclysmic variables (CVs) are close interacting binaries consisting of a red dwarf star that is transferring mass to a companion white dwarf (Warner 1995). The accreted gas forms a disk surrounding the white dwarf, and this accretion disk (AD) usually supplies most of the UV and visual luminosity of the CV. V794 Aql is classified as a nova-like (NL) CV with a likely orbital period of 3.68 hr (Honeycutt & Robertson 1998). Godon et al. (2007) report an inclination of $\sim 60^\circ$ and a distance of 690 pc.

V794 Aql is a member of the VY Scl subclass of NL CVs. The light curves of VY Scl stars display occasional low states of 1–6 mag, due to a temporary diminution of the accretion luminosity as mass transfer is interrupted. The mechanism for such a pause in mass transfer remains uncertain, although the starspot process profferred by Livio & Pringle (1994) seems plausible. The shapes of the high-state/low-state transitions in VY Scl stars have been interpreted as observational support for this starspot hypothesis (Honeycutt & Kafka 2004).

As photometry from the Indiana CV monitoring program (Honeycutt et al. 2013) has continued to grow, several earlier papers have dealt with the V794 Aql light curve at successive stages of data accumulation. The high-state/low-state transitions in V794 Aql were first discussed in Honeycutt et al. (1994a, hereafter Paper I). This work studied three transitions to the low state in 1991–1992; however, only two accompanying transitions back to the high state were observed. Transition rates were characterized using *e*-folding times τ, calculated as 1.086/(decline rate in mag day^{-1}). The *e*-folding times for the three declines were 50–100 days; for two of the three declines there was a moderate tendency for the transitions to steepen as the event progressed. By contrast the two subsequent returns to the high state were too fast to be resolved, having $\tau < 3$ and $\tau < 13$ days. Time-dependent computations (i.e., Cannizzo 1993; Lasota 2001) of the AD structure show a limit cycle behavior in which gas accumulates in the disk during the quiescent (or "cold" state) and accretes onto the white dwarf during the dwarf nova (DN) outburst (OB; the "hot" state). In such models the viscosity parameter α is generally adjusted to reproduce the observed timescales for DN OBs. Cannizzo's modeling of the V794 Aql light curve (Paper I) led to the conclusion that the declines and rises were more likely due to cooling and heating fronts in the disk (i.e., DN-like OBs) than to changes in $\dot{M}$ from the secondary star. This was mostly because the disk typically takes many tens of days to respond to a resumption of mass transfer, which is at odds with the observed very fast rises. The best agreement between the models and the light curve required $\alpha_{\rm cold} \simeq 0.005$ and $\alpha_{\rm hot} \simeq 0.005$–0.01, values smaller than those generally inferred for DN OBs.

Next Honeycutt & Robertson (1998, hereafter Paper II) analyzed the V794 Aql light curves from 1990–1996, adding four years to the earlier study. It was found that for 1993–1995 the dominant light curve pattern was as described earlier for 1990–1992. That is, for 1991–1995 we saw nearly continuous sawtooth variations with declines having $\tau \sim 50$–100 days followed by rises with $\tau < 10$ days. Most of these sawtooths occurred in the range $V \sim$14–15.5 mag, but a few declines reached 16–18 mag. As before, if the fading continued below $V \sim$15 mag, the declines became more rapid.

Finally, Honeycutt & Kafka (2004, hereafter Paper III) added 6.5 yr of data (from 1997 to mid-2003) to the V794 Aql light curve. This 1997–2003 photometry of V794 Aql was only lightly discussed in Paper III, mostly because V794 Aql stayed at $V =$ 14–15 for nearly all of that interval, having only one deep low state in 1997. A more complete analysis of the 1997–2003 data has therefore been included in this current paper. Most of that 2004 paper dealt with the systematic properties of the transitions to and from deep low states in seven VY Scl stars other than V794 Aql, and those conclusions are relevant to this

Table 1
V794 Aql Photometry by Observing Campaign

Campaign	Tel	CCD	Years	Exps	Ens Stars	Mean Err	Sec Stds	Zeropt Err
A	0.41 m	TI 800	90–91	61	78	0.020	9	0.005
B	0.41 m	Tek 512	91–05	1194	78	0.024	9	0.005
C	1.25 m	Tek 1024	07–09	153	107	0.022	9	0.004
D	1.25 m	Kodak 1024	10–12	124	85	0.020	10	0.004
E	0.41 m	Kodak 1024	11–12	84	171	0.020	9	0.005

current study. The speed and shape of 29 transitions to and from the low state (using only transitions of more than 1.5 mag in $<$150 days) were studied. Both single-slope and dual-slope rises and falls were found, with the dual-sloped transitions always being faster when fainter. It was argued that this behavior is consistent with the low states being due to a starspot on the secondary star, drifting under the inner Lagrangian point and interrupting mass transfer. Because starspots are cooler, with a smaller scale height than the rest of the photosphere, Livio & Pringle (1994) suggested that the presence of a starspot under L_1 can affect Roche lobe overflow and produce a low state. Paper III argued that the observed shapes of the transitions are consistent with the Livio and Pringle hypothesis in several respects: The dual slope transitions can be attributed to the passage of the umbral and penumbral starspot regions under L_1, while single-slope transitions can be attributed to the off-center passage of the penumbral region (only) under L_1. Furthermore single-slope ingresses were always paired with single-slope egresses, and the same was true for dual-slope transitions, as expected for the umbral/penumbral scenario.

Regardless of whether one finds the umbral/penumbral starspot arguments in Paper III convincing as the mechanism for low states, the observational properties of the VY Scl transitions in most stars differ from those described in earlier papers for V794 Aql, suggesting that the V794 Aql low states are due to a different mechanism. In this current paper we add data for 2003–2012 (but with data missing for some years), and discuss the full data set for 1990–2012 with the aid of what is now a longer and broader view of the behaviors.

2. DATA ACQUISITION AND REDUCTION

All of the V794 Aql photometry was acquired from unattended telescopes at the Morgan-Monroe Observatory of Indiana University. All of the exposures were in the *V* band, with exposure times of 2–4 minutes. A full description of the facility, the data acquisition process, the data reductions, and the observing programs can be found in Honeycutt et al. (2013). The telescopes employed, the CCD used, and the data reduction procedures varied somewhat over the 22 yr interval 1990–2012, leading us to divide the data into five campaigns, each having common properties. Because the CCD and filters varied between campaigns, we made five separate reductions to reflect the differing CCD sizes and transformation coefficients for the five campaigns. The technique of incomplete ensemble photometry (Honeycutt 1992) was used to produce the light curves. For our long-term photometry this approach has the advantages that the ensemble comparison stars can vary from exposure to exposure, and that we get a good estimate of the errors.

Table 1 summarizes the reduction process for the 1616 usable *V*-band exposures of V794 Aql. Column 1 gives the campaign designation (defined more fully in Honeycutt et al. 2013). Column 5 gives the number of usable exposures, Column 6 the number of field stars in the ensemble solution, and Column 7 the mean error of the variable. Column 8 gives the number of secondary standards used (from Henden & Honeycutt 1995) and Column 9 gives the error in the light curve zeropoint using these secondary standards. Table 2 shows a sample of the light curve data. The full version of Table 2 appears only in the online journal in machine-readable form.

Table 2
V794 Aql Light Curve Data

JD	*V* Mag	Error	Campaign
2448208.56907	14.585	0.031	A
2448209.57980	14.758	0.033	A
2448234.49495	14.214	0.023	A
2448236.49706	14.586	0.047	A
2448412.88423	14.316	0.011	A
2448425.73856	14.525	0.014	A
2448432.80939	14.653	0.035	A
....	......	.....	.
....	......	.....	.
....	......	.....	.
2456244.49969	15.160	0.017	E
2456245.50342	15.199	0.008	D
2456245.51123	15.168	0.015	E
2456246.49695	15.210	0.007	D

(This table is available in its entirety in machine-readable and Virtual Observatory (VO) forms in the online journal. A portion is shown here for guidance regarding its form and content.)

3. LIGHT CURVE DESCRIPTION

Figure 1 shows the full 1990–2012 light curve of V794 Aql. Although a few years of data are missing, the light curve is seen to have two multi-year intervals (1990–1997 and 2007–2011) containing occasional low states that are sometimes as faint as $V \sim 19$ mag. In the intervening years (1998–2004) the variations were confined to $V \sim 14$–15 mag. In some years this bright state extended faintward to $V \sim 15.5$ mag. For the purposes of this paper we will define the range $V = 14$–15.5 mag as the bright state.

In Papers I and II the change in the character of the light curve near $V = 15$–15.5 mag was only weakly apparent in the data available at the time, and our analysis therefore intermixed the two regimes on either side. For example, for the V794 Aql dual-slope transitions, described in Papers I–III, the brighter, slower portions are part of the bright state, while the faster portions are fainter than $V = 15.5$ mag. In this new analysis we have chosen to examine the bright state and the faint states separately, allowing us to study more fully the photometric phenomena in the bright state, and the connections to the faint state. This new approach does not invalidate the analysis of our earlier work, but is a different way of looking at the light curve, prompted by the

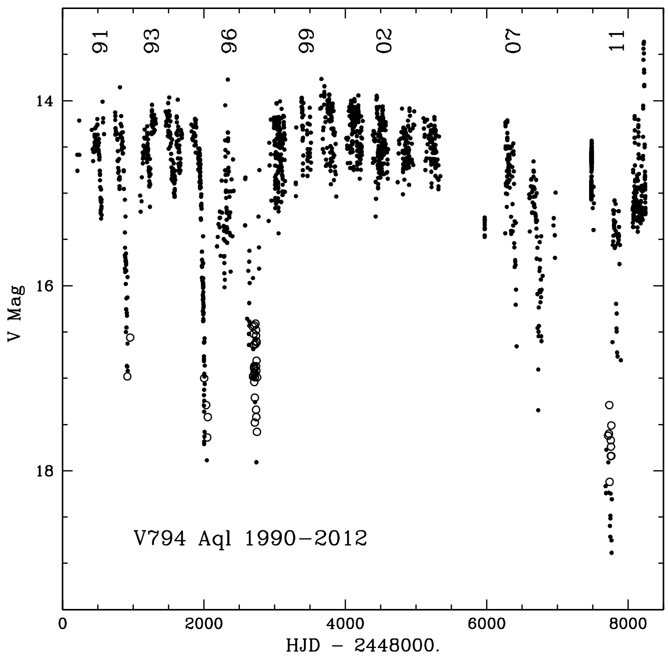

Figure 1. Full light curve of V794 Aql from 1990 November 15 to 2012 November 15 (UT). Error bars have been omitted for clarity. Along the top, the observing season is sometimes noted as a guide. The open circle symbols fainter than 16.5 mag are upper limits. The cluster of unresolved points in 2010 is three nearby nights in which 2.6 hr of continuous exposures were obtained each night; these are shown on a nightly scale in Figure 5.

distinctiveness of the bright state data that has become apparent with the addition of later exposures.

This change in approach can give rise to some confusion between the earlier papers and this work. Most of the transitions discussed in the earlier papers are considered in this paper to be either transitions within the bright state or transitions that bridge the bright state and the very faint state. The footnotes to Table 3 cross-reference the designations given to faint state transitions in common to Papers I–III. The derived e-folding times for a given transition may differ somewhat among these works due to differing techniques and slightly different Julian Date ranges employed. In this paper we have used "by eye" straight line fits, which are sufficient for our purposes.

3.1. The Faint States

Figures 2 and 3 show the six seasons that contain transitions to magnitude 16.5 or fainter, and Table 3 lists the parameters of those transitions which are reasonably well-sampled. The fourth column gives the e-folding time (in days) of the transition. The first two transitions in Table 3 correspond to the fainter, steeper sloped portions of the transitions listed in Papers I–III as dual slope events.

In order to help delineate the duration of the low states, upper limit symbols have been added to Figures 2 and 3. These additional data points help demonstrate that extended low states are not uncommon in V794 Aql. Note the 1995 interval of >50 days at V ∼17.5 mag, following the falling transition in Figure 2, and the 2011 interval of >100 days at V ∼18 mag prior to the rising transition in Figure 3.

It is of considerable interest to compare the properties of faint state transitions in V794 Aql with similar transitions in other VY Scl stars analyzed in Paper III. However, this task is complicated by the fact that Paper III made no distinction between bright state and faint state transitions but rather made

Table 3
Transitions to and from the Faint State of V794 Aql

JD-2448000	Type	V Range	τ (day)
900[a]	Fall	15.0→16.5	33
1990[b]	Fall	15.5→17.0	23
6400	Fall	14.5→16.7	22
6720	Fall	15.4→17.5	13
6740	Rise	17.5→15.5	15
7760	Rise	18.3→15.5	6

Notes.
[a] This is transition C in Paper I, transition D3 in Paper II, and transition 1 in Paper III.
[b] This is transition H2 in Paper II and transition 2 in Paper III.

single and dual slope fits to the full transitions, whatever the magnitude range. It would be possible of course to re-analyze the data of all the stars in Paper III within the context of bright states and faint states. However, it is not clear that VY Scl stars other than V794 Aql even have transitions within their bright state (more on this later). We prefer instead to discuss this issue more fully in a later paper in which we will add post-2003 data to the VY Scl stars studied in Paper III, and also add the light curves of new VY Scl stars to the discussion.

In the meantime let us use the $\tau_{\rm faint}$ column in Table 3 of Paper III as an approximation to what we have adopted as the faint state in V794 Aql, recognizing that the dividing line between bright and faint is set by a slope change in Paper III rather than by a magnitude boundary as used for V794 Aql in this current paper. For 25 transitions (in KR Aur, MV Lyr, LQ Peg, FY Per, and LN UMa, but excluding V794 Aql) we find from Paper III a mean $\tau_{\rm fall} = 26 \pm 5$(sdm) days (from 12 transitions) and a mean $\tau_{\rm rise} = 13 \pm 3$(sdm) days (from 13 transitions). By contrast we see that the V794 Aql faint state transitions from Table 3 in this current paper give a mean $\tau_{\rm fall} = 23 \pm 4$(sdm) days (from 4 transitions), and a mean $\tau_{\rm rise} = 11 \pm 5$(sdm) days (from 2 transitions). If we restrict our considerations to variations faintward from $V = 15.5$, then we conclude that faint state transitions in V794 Aql are quite similar to the transitions in other VY Scl stars. In the magnitude range 15.5–18.5 the amplitude and speeds of the transitions in V794 Aql do not appear peculiar compared to other VY Scl stars.

3.2. The Bright State

As seen in Figure 1, for most seasons the bright state data cluster strongly to the range $V = 14$–15 mag, with rather sharp edges to the magnitude distribution. For 1998–2003 there are no faint states, while for intervals before and afterward we find bright state points intermixed with faint states, which can extend down to $V = 18.8$ mag. The faint state transitions are concentrated in two intervals separated by ∼13 yr. Data is not available for 2005 and for most of 2006, so low states could have been missed during those times. If we assume that no low states occurred in 2006–2007, then the appearance of low states may be quasi-periodic, perhaps corresponding to a cycle of starspot activity. In that case Figure 1 suggests a 13 yr cycle, but with only 1.5 cycles having been observed, this is only a mild suggestion.

3.2.1. Flickering in the Bright State

On three nights in 2010 October we acquired continuous sequences of two-minute V-band exposures of V794 Aql

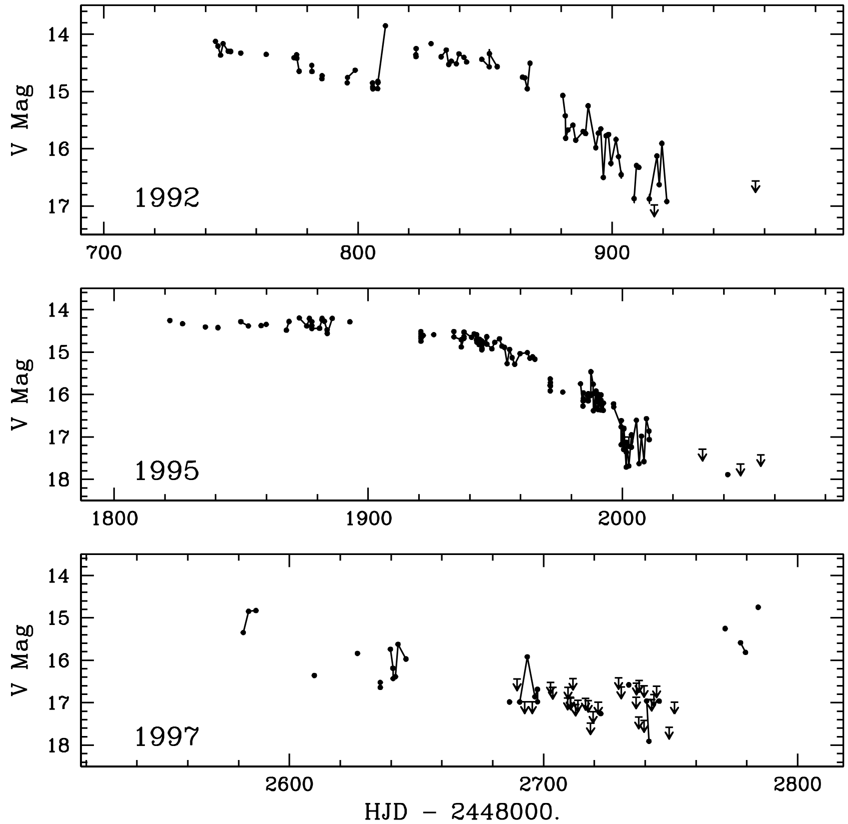

Figure 2. Light curves of V794 Aql for three seasons in which deep low states appear. Points separated by <3.5 days are connected by straight lines. Upper limit symbols (downward arrows) are plotted when they are meaningful (i.e., when they help define the duration of a low state).

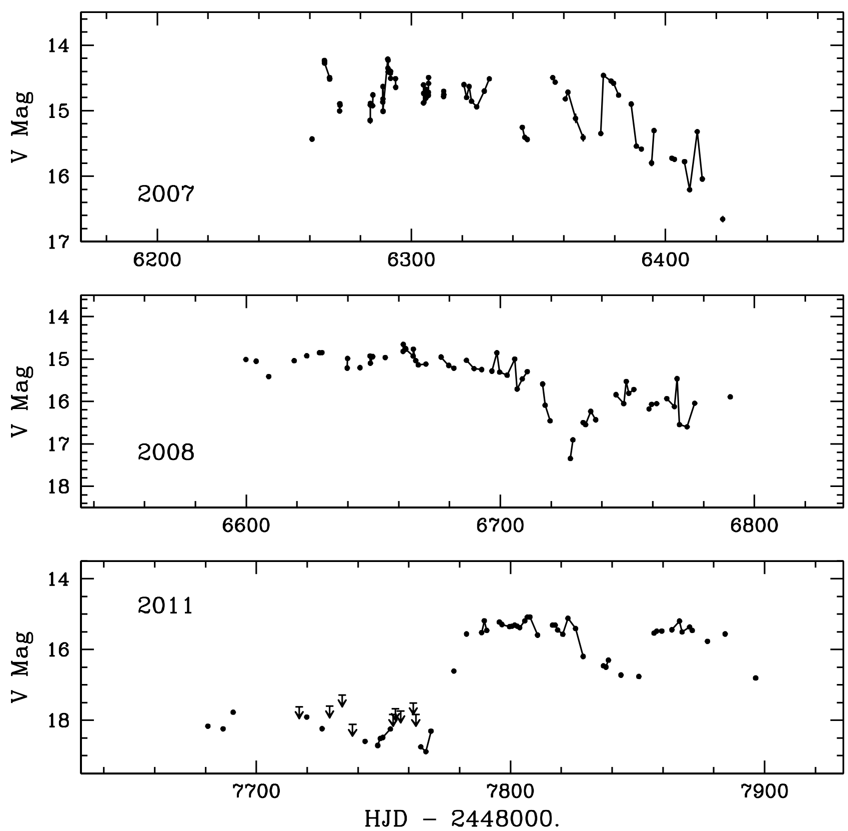

Figure 3. Like Figure 2, for three additional seasons.

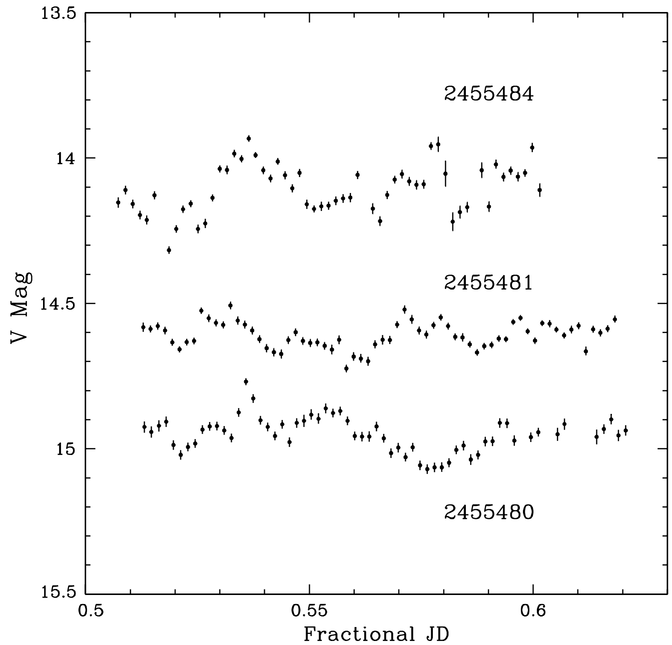

Figure 4. Photometry on three nights in 2010 October in which continuous sequences of exposures were obtained for ∼2.6 hr each night. Error bars are plotted but are mostly too small to be seen. To avoid overlap the topmost plot has been offset upward by 0.5 mag.

(Figure 4) in order to examine the strong flickering that was reported by Warner (1982). Flickering in CVs apparently can arise from a variety of locations, including the hot spot and the AD (Burch 1992). However, the flickering mechanism itself remains uncertain—see for example recent discussions in Papadaki et al. (2006), Baptista & Bortoletto (2008), Ribeiro & Diaz (2009), and Dobrotka et al. (2012). The amplitudes of variability in our data are similar to those listed in Burch (1992) for a variety of CVs. For the data in the bottom plot of Figure 4 we find a mean of 14.95 ± 0.06(sdso) mag, with 0.30 mag peak-to-peak (p-p) over 2.6 hr. The next night the mean was 14.61 ± 0.04(sdso) mag, with 0.23 mag p-p. For the third night we find a mean of 14.61 ± 0.08(sdso) mag, with 0.36 mag p-p.

The structure function (SF) is a tool for time series analysis that is often used to characterize time series data containing little or no periodicity but nevertheless having characteristic timescales of variability (Simonetti et al. 1985; Ciprini et al. 2003 and references therein); its use is especially prevalent in the active galactic nucleus literature. The SF is closely related to the autocorrelation function and basically measures the rms scatter among pairs of data points which are separated by a particular spacing, or lag τ. In the region of interest the SF is usually a power-law SF $\propto \tau^{\beta}$. Most of the measures of flickering noise in the CV literature are made using power spectral density (PSD), often computed using the periodogram. In the region of interest the PSD is also a power-law PSD $\propto f^{\alpha}$, where f is the frequency (usually in days^{-1}). For equally spaced data of infinite length an SF analysis is equivalent to a PSD analysis (Paltani 1999), but the SF is considered to have some advantages for studying the noise properties of real astronomical data. For example, the SF is easier to compute and is less dependent on the sampling. We have used $\alpha = -(1+\beta)$ as the relationship between SF and PSD indices, where α and β are the power-law exponents for the dependence of the SF and the PSD, respectively, on lag and frequency (respectively).[4]

We made a log(SF) versus log(τ) plot using the data in Figure 4, over a τ range from 5 minutes to 140 minutes. For $\tau \lesssim 25$ minutes the slope is $\beta \simeq 0.5$, which corresponds to $\alpha \sim -1.5$. For $\tau \gtrsim 25$ minutes the log(SF)/log(τ) relation flattens, meaning that 25 minutes is the longest characteristic timescale for the flickering noise in V794 Aql. Using the results of flickering studies found in Baptista & Bortoletto (2004), Papadaki et al. (2006), Baptista & Bortoletto (2008), Ribeiro & Diaz (2009), and Dobrotka et al. (2012), the values of α in NL CVs are typically −1.3 to −1.8 and the cutoff frequency or knee typically corresponds to a characteristic timescale of 20–100 minutes. The fact that the flickering properties in V794 Aql are not unusual means that we must look elsewhere for clues to the other light curve peculiarities of V794 Aql.

3.2.2. Outbursts and Transitions within the Bright State

In Figures 5–10 we plot the data in the range $V = 14$–15.5 mag season by season. A variety of features are seen, including slow undulations, occasional sequences of small OBs, and slow declining ramps of 0.5–1.5 mag. These declines are often followed by a rapid rise, giving the light curve at times a sawtooth appearance. In 1992 and 1995 slow declines led into more rapid descents into the faint state (see Figure 2), which led to the dual-slope characterization in Papers I–III. That behavior is not apparent for later transitions to the faint state in V794 Aql (see Figures 2 and 3). Finally, the light curve sometimes shows erratic behavior that is not possible to classify, an appearance that can be enhanced by incomplete sampling at times.

We find occasional intervals in which the events are best characterized as OBs, separated by quiescent levels. The best example can be seen in Figure 10 in which three successive 2012 OBs are visible with separations of 52 and 75 days, amplitudes of 1.0, 1.0, and 1.9 mag, and FWHM of 6, 8, and 18 days. The rises are somewhat faster than the declines. We find *e*-folding times in days of 6/10, 6/13, and 7/11 for the rise and fall, respectively, of the three OBs.

In the 1996 light curve of Figure 6 a pair of very similar OB-like events occur which nearly straddle the bright/faint state boundary we adopted. The two events are separated by 36 days. Each shows a very rapid rise of ∼2 mag to a sharp peak, falling very quickly by ∼0.4 mag before beginning a more leisurely decline. We will call these distinctively shaped events "hiccups." A 1992 event in Figure 5 may be another hiccup, but is more poorly sampled than the 1996 pair.

In the 2001–2002 light curves of Figure 8 the OB-like events are more like sawtooths, with characteristic spacings of 25 days and amplitudes of ∼0.6 mag, while in the 2003 light curve of Figure 8 the spacings and the amplitudes are reduced to ∼12 days and ∼0.4 mag, respectively. Overall it appears that V794 Aql often has OB-like features, but the strengths, shapes, and spacings of these OBs change significantly from year to year.

Table 4 summarizes the properties of the small OBs in V794 Aql for five seasons in which they were fairly conspicuous.

[4] Several authors (e.g., Hughes et al. 1992; Tosti et al. 2001; Collier & Peterson 2001; Kataoka et al. 2001; Ciprini et al. 2003) provide the relationship $\alpha = -(1+\beta)$, while others (e.g., Kawaguchi & Mineshige 1999; Bauer et al. 2009; Vagnetti et al. 2011) use $\alpha = -(1+2\beta)$. These two equations have a relatively small numerical difference in the ranges of α and β that we are considering, and the distinction has no effect on our conclusions.

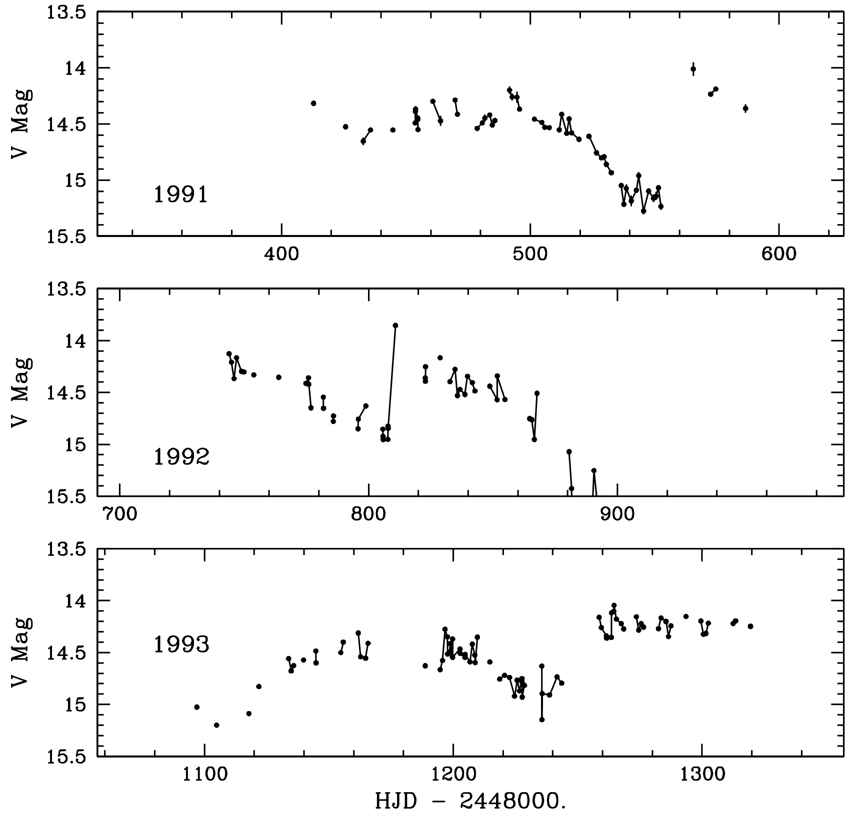

Figure 5. First of a series of six plots showing the high-state V794 Aql light curve season by season. Points separated by less than 3.5 days are connected by straight lines. Error bars are plotted but are mostly too small to be seen. To facilitate comparison, most of the plots have a common magnitude range from 15.5 to 13.5; however, a few panels have somewhat extended ranges in order to include particular features. A few seasons are missing because either data were not acquired, or high-state data were very sparse.

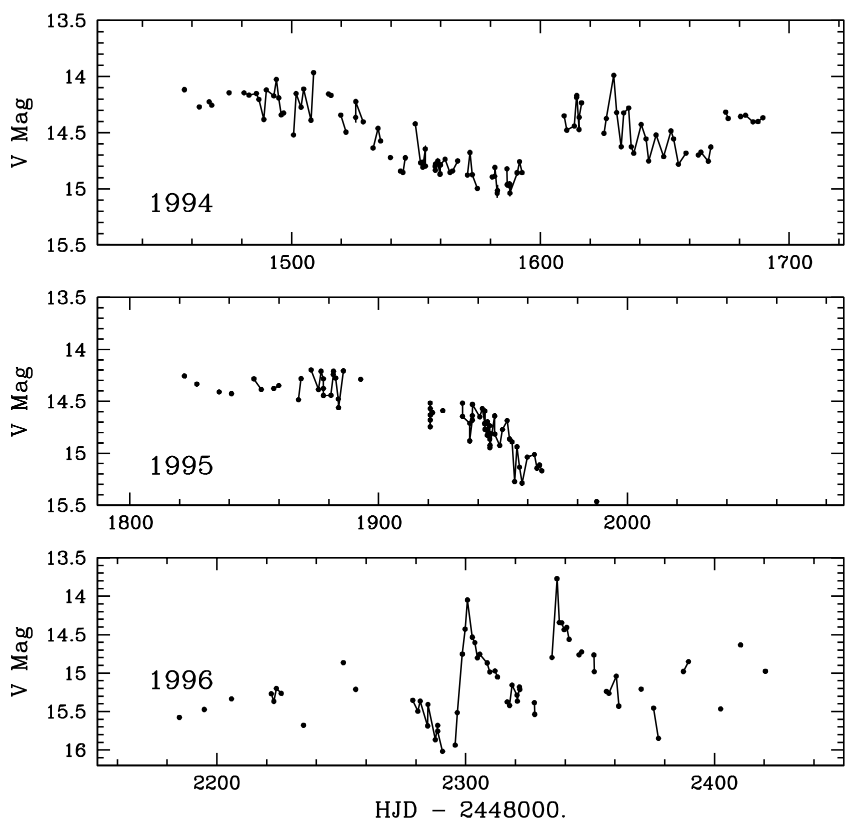

Figure 6. Same as Figure 5, but for three additional seasons.

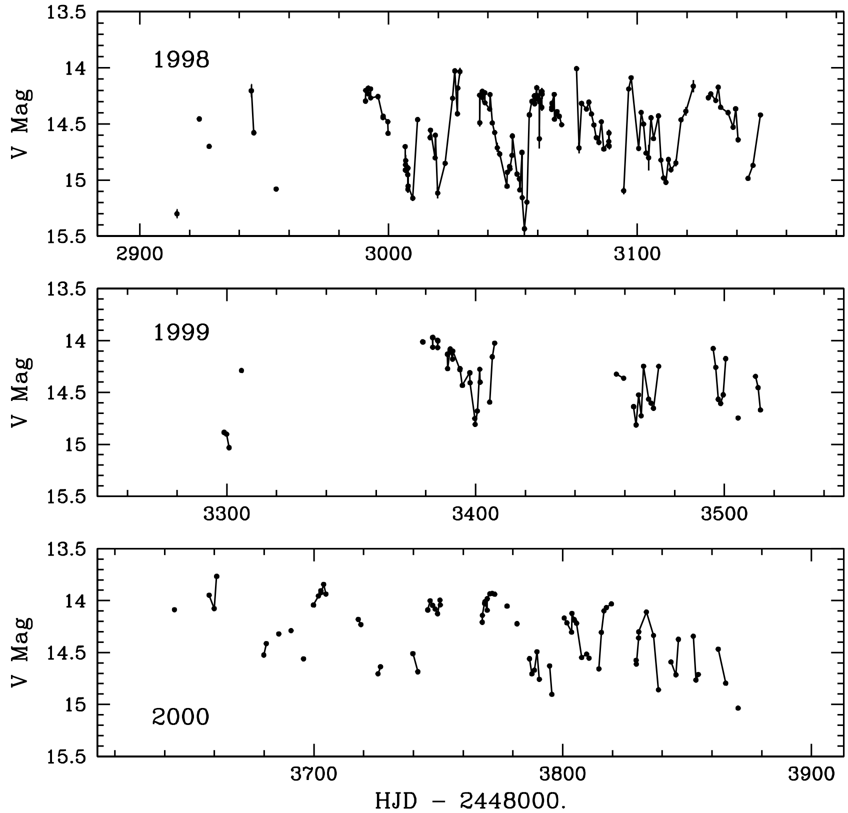

Figure 7. Same as Figure 5, but for three additional seasons.

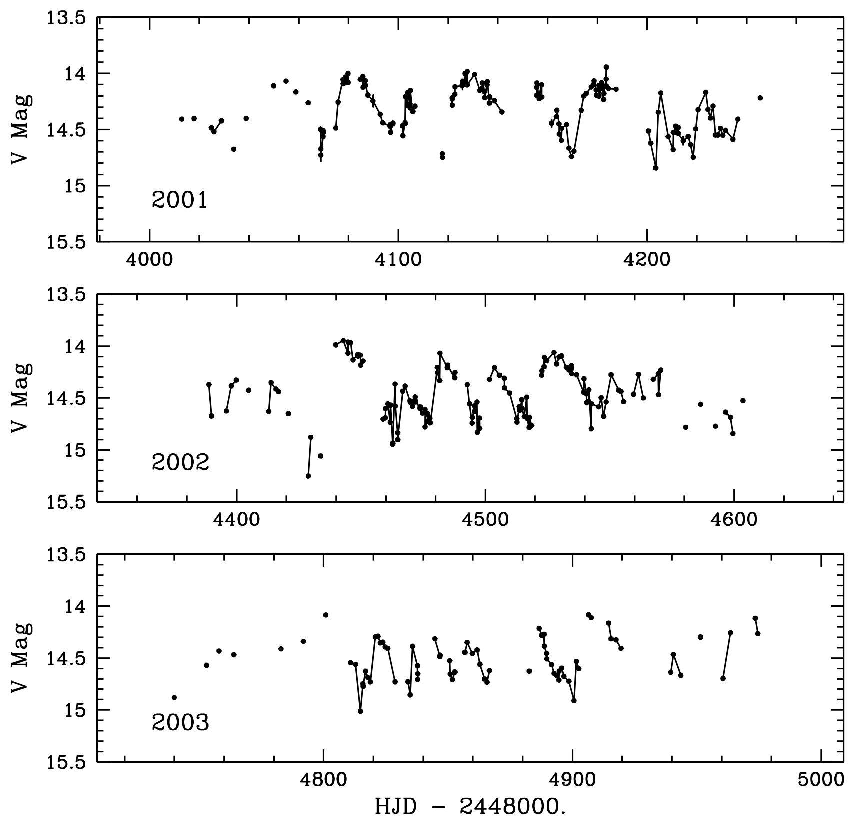

Figure 8. Same as Figure 5, but for three additional seasons.

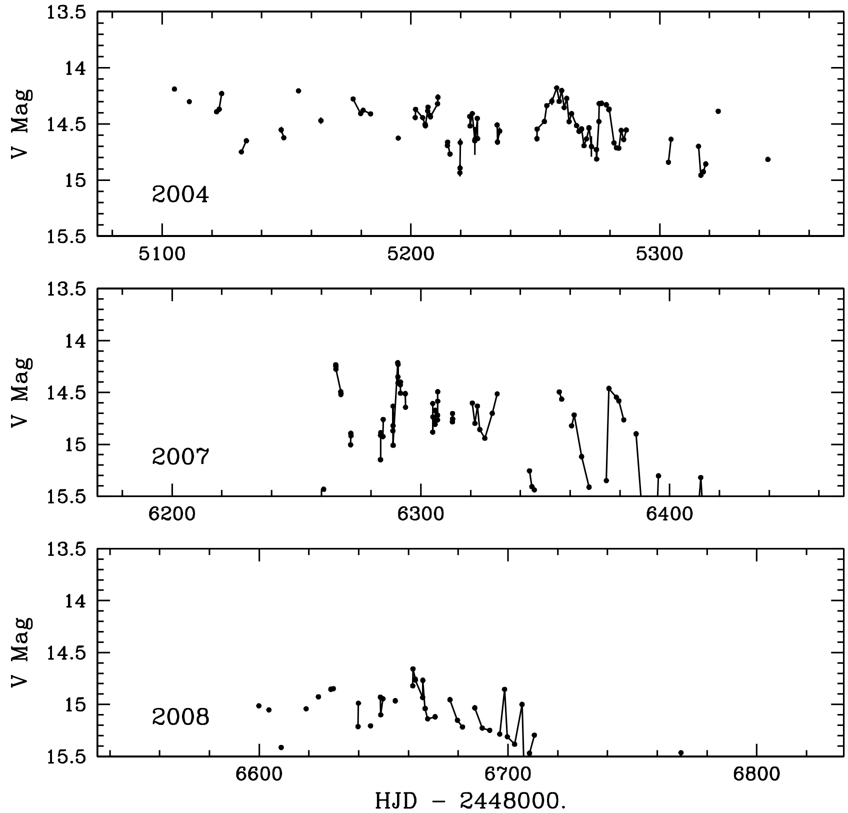

Figure 9. Same as Figure 5, but for three additional seasons.

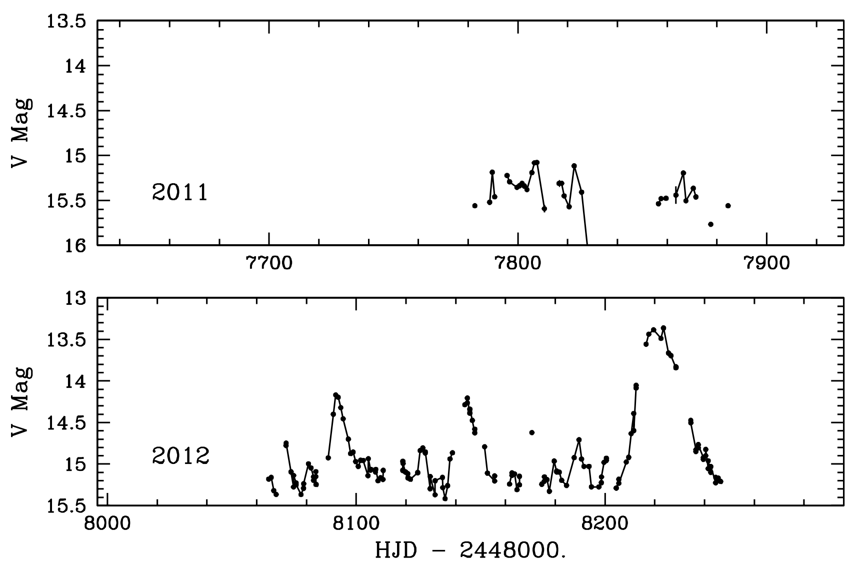

Figure 10. Same as Figure 5, but for three additional seasons.

Although some additional seasons have features that resemble OBs (e.g., year 1998 in Figure 7), such wiggles are often too irregular to characterize; only the five seasons in Table 4 have sequences of OBs that are fairly regular. Even so, the table entries have still some peculiarities. For example, the 1996 entry is for the two hiccup events, whose nature is uncertain but which have been included in the table so that their properties can be compared to the more regular sequences. The OBs in 2001 and 2002 are similar and have been combined. The OBs in 2003 are small and beginning to be lost in the chatter, but OBs return conspicuously in 2012. Note that for all five seasons in Table 4 the rise time is significantly faster than the fall time (but to varying degrees). There is a weak correlation of amplitude and spacing for the last three entries in Table 4. The 1992 hiccups seem to differ from the OBs in the other four seasons and therefore should probably not be called OBs at all.

4. DISCUSSION

In Paper I the main objection to attributing the V794 Aql transitions to changes in $\dot{M}$ from the secondary star was the fast recovery back to high state. The disk tends to mediate the

Table 4
Small V794 Aql Outbursts

Year	No. OBs	Ampl (mag)	Spacing (days)	FWHM (days)	τ_{rise} (days)	τ_{fall} (days)
1996[a]	2	1.7 ± 0.1	36	13 ± 2	4 ± 0.4	1.5 ± 0.2
						34 ± 1
2001–2002	7	0.6 ± 0.05	25 ± 1	14 ± 1.5	8 ± 1	31 ± 2
2003	4	0.5 ± 0.07	14 ± 2	7 ± 1.5	10 ± 1.5	19 ± 3
2012	3	1.7 ± 0.3	64 ± 16	12 ± 4	6 ± 2	11 ± 1

Notes. All errors are standard deviations of the mean.
[a] The two 1996 OBs are the oddly shaped hiccups. There are therefore two entries for τ_{fall}: the initial rapid decline followed by a slower fall.

Table 5
Comparison of Mean *e*-folding Times for Faint State Transitions

Transition Type	Num.	Mean τ	Fall/Rise Ratio
Faint state falls in V794 Aql	4	23 ± 4	2.1 ± 1.0
Faint state rises in V794 Aql	2	11 ± 5	
Faint state falls in others[a]	25	26 ± 5	2.0 ± 0.6
Faint state rises in others[a]	13	13 ± 3	

Notes. All errors are standard deviations of the mean.
[a] From five VY Scl stars in Paper III other than V794 Aql.

effect on the light curve of the resumption of $\dot{M}$, and the rise times quoted in Paper I of <3 days and <13 days were a strong argument against these transitions being due to a resumption of mass transfer. However, in Paper I we made no distinction between transitions within the bright state and transitions to the true deep faint state, because that distinction was not obvious in the light curve up to that point. As it turns out, the two fast rises in Paper I occurred during what we are now calling the bright state. The third faintward transition discussed in Paper I did extend well into the faint state regime, but the following rise to the bright state was missed. Therefore it is legitimate for us to now argue that the transitions to and from the true (very) faint state of V794 Aql are indeed due to changes in $\dot{M}$. Extended intervals of nearly constant brightness on either side of the transitions in the faint state (see Section 3.1) seem to rule out that AD heating/cooling fronts play a role for the V794 Aql light curve fainter than magnitude 15.5. Intervals of months/years spent in the high state, followed by months at a nearly constant faint magnitude are a common property of VY Scl stars, not of variability due to the thermal/viscous instability.

The *e*-folding times for the declines and falls within the faint state of V794 Aql do not differ from those of VY Scl type high/low transitions in other NL CVs (see Section 3.1 and Table 5), providing additional evidence that in the faint state V794 Aql has unremarkable VY Scl type behavior. The mean *e*-folding time of the recoveries from the low state in V794 Aql are $\langle\tau_{rise}\rangle = 11 \pm 5$(sdm) days, and this is $\sim 2\times$ faster than $\langle\tau_{fall}\rangle = 23 \pm 4$(sdm) days. If this recovery timescale represents the rebuilding of the disk after an $\dot{M}$ turnoff, then this rapid transition presents something of a problem for eliminating a disk heating-front transition as the mechanism (Honeycutt et al. 1994a). Similarly, the fact that $\langle\tau_{fall}\rangle \sim 2\times\langle\tau_{rise}\rangle$ is something of a problem for the umbral/penumbral scenario for VY Scl low states, because it implies that somehow the drift speed of the starspot becomes faster as it crosses L_1. However, these two issues exist for *all* the VY Scl light curves in Paper III, so our conclusion that V794 Aql does not have unusual transitions

Table 6
Oscillatory Stunted Outbursts in Nova-like CVs

Star	Spacing (days)	Ampl (mag)	Character	Refs
FY Per	28	0.7	Oscil[a]	5
RW Tri	25	0.45	Oscil	1, 2, 5
DI Lac	37	0.5	Quasi[b]	2, 4, 5
V794 Aql	15–60	0.5–1.7	Quasi	This paper
V841 Oph	36	0.4–0.8	Quasi	1, 2, 4
GI Mon	60	0.9	Quasi	5

Notes. All errors are standard deviations of the mean.
[a] Mostly continuous oscillations.
[b] Quasi-regular.
References. (1) Honeycutt et al. 1994b; (2) Honeycutt et al. 1995; (3) Honeycutt et al. 1998a; (4) Hoard et al. 2000; (5) Honeycutt 2001.

to and from the faint state remains valid. This is, whatever mechanism operates in most VY Scl stars to turn on and off the mass transfer appears to also be responsible for the light curve of V794 Aql, for *V* fainter than magnitude 15.5.

Turning now to the bright state variations in V794 Aql, the small OBs seen during some seasons have properties very similar to those described in Honeycutt et al. (1998a) and in Honeycutt (2001) for stunted OBs which are found in some NL CVs. Table 6 lists some of the properties of stunted OBs which appear, at least sometimes, as continuous oscillations. V794 Aql has been included in the table for comparison. Stunted OBs often are erratic, especially from season to season. The stars in Table 6 have been arranged in order of decreasing reliability of the stunted OB oscillations. In these cases, reliability is decreased when the oscillations appear in fewer seasons, and/or if the oscillations are less stable in separation interval and shape, and/or if the amplitude envelope becomes more ragged. Apart from the large amplitude OBs in 2012, the amplitude of the V794 Aql OBs are similar to those of the oscillations in the other stars, and the spacing is in the expected range. We therefore conclude that the activity in the bright state of V794 Aql is also due to stunted OBs, with reliability falling in the mid/lower range of the stars listed. Stunted OBs can also appear in some NL CVs as more widely spaced events arising from a quiescence level (Honeycutt et al. 1998a), but such events might be difficult to see in V794 Aql against the erratic bright state variations present in many seasons.

The mechanism for the generation of stunted OBs is not well-established. DN occupy the mid-range of $\dot{M}$ in CVs, a range in which the partial ionization of hydrogen can result in cooling and heating fronts in the AD. These lead to an alternation between a hotter, brighter, mostly ionized disk and one that is cooler, fainter, and mostly neutral, producing DN OBs (Cannizzo 1993; Lasota 2001). In general DN OBs have faster rise times than fall times by $\sim 2\times$ (Warner 1995), similar to the asymmetry of the small OBs in V794 Aql.

If $\dot{M}$ from the secondary star exceeds $\dot{M}_{crit}$, the disk stays in the brighter state, without DN OBs, resulting in an NL CV. Near $\dot{M}_{crit}$ the system can exhibit the Z Cam phenomenon, in which DN OBs are interrupted by standstills as $\dot{M}$ exceeds $\dot{M}_{crit}$. Appealing to AD models, we find that as $\dot{M}$ slowly approaches $\dot{M}_{crit}$ from the low side, the DN OBs are quenched in amplitude and the spacing decreases until the duty cycle becomes 100% (Lin et al. 1985), producing events that might resemble the oscillatory stunted OBs in Table 6. This quenching, accompanied by a transition to continuous OBs, can be seen in observations of Z Cam OB/standstill transitions (Honeycutt et al. 1998b).

It seems reasonable for us to assume that the stunted OBs in V794 Aql are due to an $\dot{M}$ that is very near $\dot{M}_{\rm crit}$. However, concerns remain. First, it is surprising that such a large fraction of the NL CVs would linger so near $\dot{M}_{\rm crit}$. Secondly, there is no apparent correlation of $\dot{M}$ (using V magnitude as a proxy) with the likelihood of seeing stunted OBs from season to season. (Honeycutt et al. 1998a; Honeycutt 2001). One might expect that stunted OBs would selectively appear when a system was fainter (i.e., below $\dot{M}_{\rm crit}$). With regard to V794 Aql specifically, it is somewhat bothersome that the spaced stunted OBs in the stars discussed in Honeycutt et al. (1998a) have similar $\tau_{\rm rise}$ and $\tau_{\rm fall}$, while the stunted OBs in V794 Aql have faster rises than falls by a considerable margin (see Table 4). Concerns such as these led Honeycutt et al. (1998b) and Honeycutt (2001) to consider a wide range of other possible mechanisms for stunted OBs. These suggestions included nuclear burning at the magnetic pole of the white dwarf serving to veil normal DN disk OBs, a disk truncated by the magnetic field of the white dwarf, or a very hot white dwarf preventing the inner disk from participating in the thermal–viscous instability. Overall, Z Cam like OBs remain a reasonable candidate mechanism for stunted OBs, but with work remaining to solidify the case.

It should also be pointed out that the bright state variations in V794 Aql that occur during seasons without stunted OBs also have interesting properties. Let us call these the "off-seasons." Some of these off-season variations are probably due to incomplete sampling of unrecognized stunted OBs, but additional effects are present. The ramps seen in the off-seasons display faster rises than falls, as expected for portions of stunted OBs. However, the declining ramps are often much slower than for stunted OBs (e.g., see the slow undulations found in the 1991–1996 light curves of Figures 5 and 6), and occasionally the rising ramps are much faster than the rising portions of stunted OBs (see the unresolved brightward excursions in the 1992 data of Figure 5 and the 1998 data of Figure 7). In spite of the off-season ramps having both faster and slower e-folding times than the rises and falls of the stunted OBs, the range of variability during the off-seasons remains confined to very nearly the same range as that of the stunted OBs. The common range of variability for phenomena in the bright state led to the rather striking concentrations of data between 14.0 and 15.0 mag for 1998–2004, which can be seen in Figure 1.

V794 Aql is not alone in displaying both oscillatory stunted OBs and VY Scl type low states. FY Per also shows this combination (Honeycutt 2001). In FY Per the VY Scl low state was brief and isolated, making it very distinct from the stunted OBs, and avoiding the confusion of the two phenomena that arose for V794 Aql. Nevertheless, this combination of stunted OBs and VY Scl low states is quite rare among the ∼75 old nova and NL CVs monitored at Indiana.

5. SUMMARY AND CONCLUSIONS

V794 Aql is argued to have two distinct kinds of photometric phenomena. First, one finds 0.5–1.7 mag OBs during the bright state ($V = 14.0$–15.5). In some years these appear as continuous ∼25 day oscillations, in other years as larger, more widely spaced OBs, or as fragments of OBs. Similar behavior is found in the light curves of a number of other NL CVs, although the oscillations and OBs are rather more erratic in V794 Aql. Second, one finds occasional excursions to a V ∼18 mag faint state. The properties of the transitions to and from the faint state do not differ substantially from those of other VY Scl type stars, leading us to conclude that the low states in V794 Aql are not unusual.

However, the *combination* of these two kinds of variability in the same NL CV *is* unusual. During the interval 1991–1998 the two phenomena were rather thoroughly intermixed in the V794 Aql light curve, leading to earlier characterizations of the V794 Aql long-term light curve that have proven to be misleading. The following descriptions cleanly separate the behaviors on either side of $V = 15.5$ mag.

For V fainter than 15.5 mag:

1. During the years 1991–2012 six excursions to deep low states were detected, with the faintest detected magnitudes in the range 16.7–18.7 mag. Four of the low states displayed extended plateaus at the faint level, with durations ranging from 50 to 100 days.
2. As part of our descriptions of the V794 Aql transitions in Papers I–III, some declining portions of OB and OB-like behavior in the bright state were identified as portions of transitions to the low state. However, when we restrict attention to V fainter than magnitude 15.5, we find that the average e-folding time of the four detected falls to the low state in V794 Aql was 23 days, compared to 26 days for 25 falls to the faint state in other VY Scl stars. The average e-folding time of the two detected rises from the low state in V794 Aql was 11 days, compared to 13 days for 13 rises from the faint state in other VY Scl stars.
3. Therefore, based on the extended low state plateaus and the comparisons of the e-folding times, the faint state properties of V794 Aql are those of a normal VY Scl star.

For V brighter than 15.5 mag:

1. Sequences of quasi-periodic stunted OBs are seen in 4 of 20 observing seasons. Most of these OBs display continuous oscillations. The OBs have amplitudes of 0.5–1.7 mag and spacings ranging from 14 to 64 days. The amplitudes and spacings change from season to season but remain relatively constant within a season.
2. During seasons in which sequences of stunted OBs are not apparent, more random photometric variations are present. These variations remain restricted to the same magnitude range as the stunted OBs.
3. Comparisons of the properties of stunted OBs in other NL CVs show that the OBs in V794 Aql closely resemble those of other stunted OBs described in the literature.

   Overall, we find that V794 Aql displays two different light curve phenomena: stunted OBs and VY Scl low states. The mechanisms responsible for these two effects remain uncertain. However, the two phenomena are separately well documented in other NL CVs, and their manifestations in V794 Aql appear unremarkable compared to the other examples. The combination of the two effects in the same star is rare, but not unprecedented.

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